Precise screw positioning at the mandibular angle: computer assisted versus template coded

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Abstract: BACKGROUND: Buried intraoral devices for distraction osteogenesis in mandibular deformities have numerous advantages, but success depends on the precise positioning of these devices. Although most centers nowadays use template-guided techniques for precise positioning, computer navigation has been described as a promising technique. Surgical navigation during device placement could become a viable method because it affords certainty in defining a device position. METHODS: A clinical situation was simulated by means of mounting a mandible model inside a phantom head. Screws were positioned according to a preoperative plan through transoral and transbuccal approaches, with both template-coded and freehand computer navigation. RESULTS: With template-coded navigation, the medium deviation from the planned position was 0.63 mm (range, 0.00-1.24 mm). With commercial freehand surgical computer navigation, the medium deviation was significantly higher at 0.98 mm (range, 0.00-3.13 mm). CONCLUSIONS: Computer-assisted surgery can provide a high level of accuracy in the region of the mandibular angle where precision is crucial for buried intraoral distraction devices. However, template-coded guidance does provide a significantly higher level of accuracy and therefore represents the gold standard.

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Precise screw positioning at the mandibular angle: Computer assisted vs. template coded

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Abstract

Background

Buried intraoral devices for distraction osteogenesis in mandibular deformities have numerous advantages, but success depends on the precise positioning of these devices. While most centers nowadays use template-guided techniques for precise positioning, computer navigation has been described as a promising technique. Surgical navigation during device placement could become a viable method because it affords certainty in defining a device position.

Materials and methods

A clinical situation was simulated by means of mounting a mandible model inside a phantom head. Screws were positioned according to a preoperative plan through transoral and transbuccal approaches, with both template-coded and freehand computer navigation.

Results

With template-coded navigation, the medium deviation from the planned position was 0.63 mm (range 0.00 – 1.24 mm). With commercial freehand surgical computer navigation, the medium deviation was significantly higher at 0.98 mm (range 0.00 - 3.13 mm).

Conclusions

Computer-assisted surgery can provide a high level of accuracy in the region of the mandibular angle where precision is crucial for buried intraoral distraction devices. However template-coded guidance does provide a significantly higher level of accuracy and, therefore, represents the “gold standard.”

INTRODUCTION

In most situations exact screw positioning in the mandibular angle region is not a relevant issue as long as basic rules are followed. For example, in trauma cases the surgeon aims at the lower border of the mandible and the linea obliqua. Both are easily visible, and the judgment is simple. In orthognatic surgery the nerve is visible, and, in addition, the surgeon has some discretion in positioning the screws.

The situation is different in cases of distraction osteogenesis where the exact placement of the distraction device is crucial to the applied vector and, therefore, to the resulting bone formation; and this scenario has been discussed in the literature.[1, 2] The importance of precise preplanning and distractor positioning applies especially to small intraoral distraction devices, which do not allow manipulations of the distraction vector during the distraction period, but depend fully on their initial placement. The promising new technique of semiburied curvilinear distractors, as described by Kaban and Troulis et al., is dependent on correct placement of the distractor in a special way.[1] Yeshwant et al. showed that an infinite number of different devices can achieve all the distraction pathways necessary due to different positions of the devices.[3, 4]

The clinical practicability for navigation of the lower jaw has been shown before.[5-9] Our group recently published an article in the *Journal of Craniofacial Surgery* regarding the superiority of surgical navigation for exact screw positioning in the mandibular angle region.[10] The article compared the precision achieved with freehand screw positioning with an experimental navigation system. The results elicited two general types of comments from our colleagues, as follows:

a) The range of inaccuracy seen under computer navigation is a result of the preliminary status of the utilized navigation system and would be much lower with a commercial system.

b) Template coding for the screw positions - the technique clinically used in most centers – is much more accurate than computer navigation and is, therefore, the “gold standard.”

Aim of the study

The aim of the study was to evaluate screw placement as necessary for positioning buried distraction devices in a planned position in the mandibular angle region through an intraoral approach, and to examine the accuracy of a commercially available computer navigation system, on the one hand, and of a template-based technique, on the other hand.

Both techniques should be discussed regarding advantages and disadvantages beyond accuracy and should be placed in the context of previous results.

Material and Methods

A mandible model (3B Scientific, Hamburg, Germany) was prepared with 12 drill holes (1.2 mm)—6 on each side—which represented designated screw positions in the region of the mandibular angle. This mandible served as a “reference model” and “treatment plan.” A prefabricated splint bearing

5 titanium screws (System Modus 1.5, 6 mm; Medartis AG, Basel, Switzerland) was individualized and adapted to the model's dentition (Figure 1). With the splint affixed, the reference model was then scanned into computer tomography, and the resulting dataset served for extracting a virtual 3D model. The entry points of the drill holes were labeled in the iPlan® CMF Software (Version 3.0; Brainlab AG, Feldkirchen, Germany), and these labels served as a surgical plan for navigated screw positioning. The titanium screws fixed to the splints were marked as fiducials, and they served for the registration process before surgical navigation. Figure 2 shows the virtual model after the planning process.

For template production, 1.2 mm steel sticks were placed into the holes and, with a light-curing custom tray material, based on a hybridcomposite (Plaque Photo; Willmann & Pein GmbH, Barmstedt, Germany), a template was constructed over the bone surface and partially over the dentition. After polymerization of the template with ultraviolet light, the steel sticks were removed, and the resulting holes were ready to serve as guides (Figure 3). A total of 10 templates were constructed – 1 for each side of every mandible to be tested by the template technique – in order to exclude any effects from wear during the process.

A total of 10 identical mandible models served as test models for screw placement and evaluation – 5 using surgical navigation, 5 template based. All surgeries were performed by the same maxillofacial surgeon. He had experience with navigated procedures as well as with classical non-navigated surgery in the mandibular angle region. The surgeon was assisted by a trauma surgeon to help with, for example, cheek retraction and positioning the pointer device.

Template-based screw positioning

The test mandible model was mounted inside a dental phantom head as shown in Figure 4, and an unused template was positioned. The position was manually secured by the assisting surgeon. Through the transbuccal approach and the guidance holes of the template, drilling was performed. Six titanium screws (System Modus 1.5, 6mm; Medartis AG, Basel, Switzerland) were inserted on each side of the mandible angle region. This procedure was repeated for a total of 5 test models for template-guided screw placement.

Navigated screw positioning

The VectorVision^2 system used (Brainlab AG, Feldkirchen, Germany) is a commercially available navigation system using passive infrared reflecting balls which are attached to a dynamic reference frame (Figure 1) and to a pointer. A camera belonging to the system identifies the positions of the dynamic reference, and therefore the patient/model and the pointer.

First, the test model was prepared with a rigidly fixed base for the dynamic reference. The mandible model was mounted inside the phantom head, and the dynamic reference was fixed to the base. The system was registered by point-to-point registration via the 5 fiducials attached to the registration splint.[11] Accuracy was checked against broad areas of the model's surface with 600% magnification on the screen.

The navigated pointer device was inserted transorally and used to identify screw entry points on the mandibular surface. This was performed under 600% magnification by the assisting surgeon until the lowest practical achievable distance between pointer position and label was found. Drilling and screw positioning was performed by the maxillofacial surgeon via a transbuccal approach. The pointer tip was then positioned onto the inserted screw's head, and the distance according to the preoperative plan was evaluated (Figure 5). The screw was eventually repositioned according to the maxillofacial surgeon's recommendation until a satisfactory match with the navigated result was achieved. During the procedure, accuracy checks against landmarks and already positioned screws were performed before a new screw was positioned. Five test models were navigated bi-laterally according to this approach.

Evaluation

Photos of all mandibles (1 reference and 10 test) were taken from a defined angle and distance. With the use of Photoshop CS 4 (Adobe Systems Incorporated, San Jose, CA, USA), the photo of the reference mandible and the photos of the test models were precisely overlaid with one another. The drill holes in the reference model were marked with a cross and the screw positions with color-coded dots.

A digital caliper was used on the photos to measure the distance between the screws on the test models and the holes in the reference model. According to the rule of proportion, the deviation of each screw from its planned position was measured on the x-axis (mesio-distal) and the y-axis (caudo-cranial).

The acquired data was analyzed using descriptive statistics as well as parametric Student's t-tests. The tests were performed with SPSS 11.5 (SPSS Inc, Chicago, IL, USA) and were considered significant if $p<0.001$.

Results

Designing the reference mandible and producing the templates was uneventful. After the computer tomographic data from the reference mandible had been imported into the navigation system's planning software, all fiducials and all holes drilled as reference screw positions were clearly visible and could easily be marked. The 3D surface reconstruction was performed using an automated threshold algorithm that is integrated into the navigation package.

The phantom model and draping created a realistic situation in terms of working angles and accessibility. The retraction forces to be applied during model surgery were different from applied in real patients, but this did not influence the assessment of screw positions. The fixation of the dynamic reference frame was stable in all procedures.

The registration process of the navigation system was fast and simple, aided by the fiducials. A registration result of deviation less than 1 mm was achieved in all procedures with the first registration.

The overlay evaluation showed a distribution close to the planned screw positions in the navigated procedures (Figures 6a and 6b). The average deviation was 0.98 mm (range 0.00 - 3.13 mm, standard deviation 0.67 mm) as a straight line distance (Figures 6c and 6d).

The template-coded procedures showed an even higher precision, with the screw positions almost exactly on the planned location (Figures 7a and 7b). The average deviation was 0.63 mm (range 0.00 - 1.24 mm, standard deviation 0.21 mm) as a straight line distance (Figures 7c and 7d).

The deviations for the template-coded procedure were significantly lower than the ones for the computer-navigated procedure. Both evaluated techniques also showed a significantly higher precision than the previously evaluated ones (Figure 8).[10]

There was a noticeable tendency in the direction of the seen deviations. The error in the mesio-distal direction seemed to be lower than in the cranio-caudal direction in both the computer-navigated and template-coded procedures. However, the difference was not significant (Figure 9).

Discussion

The aim of this study was to find out, first, if a commercially available navigation system would be more accurate in screw positioning at the mandibular angle than the previously studied[10] experimental one and, second, if template-coded screw placement would be even more accurate.

Both techniques should also be discussed regarding advantages and disadvantages beyond accuracy.

With an average deviation of 0.98 mm (range 0.00 - 3.13 mm), commercial navigation proved to be significantly superior to the experimental system evaluated previously (Figure 8).[10] There was no systematical error (Figure 9). Compared to both computer-navigation systems, the template-coded screw positioning proved to be significantly more precise (average deviation: 0.63 mm, range 0.00 - 1.24 mm) (Figure 8). Neither the template-coded nor computer-navigated procedure showed any major difficulties in planning or intraoperative handling. Templates represent the "gold standard" when it comes to precision.

The weakness of the present study obviously lies in the model-based approach, which can never represent reality perfectly. However, regarding the aim of the study, the model does represent all necessary parameters of reality as, e.g., the angle of the surgical approach and field of vision. Beyond that it also excludes influencing factors as, e.g., different target regions for different patients that might interfere with a precise statistical analysis.

In a clinical context, as described by Kaban and Troulis et al.[1], one major concern does occur regarding the template-coding technique: a certain amount of imprecision is introduced in the transfer of the virtual plan onto the real model needed for production of the template – especially since the imprecision of free judgment has been reported before.[1, 10] A direct transfer of the virtual plan into the guidance tool, however it is designed, would clearly be preferable.

Further studies should calculate how much of the error in placement of the distraction device results in how much error after the distraction procedure. Since molding techniques are regularly applied to the generated bone[1, 12], they have to be taken into account. A similar effect might occur because of the muscle forces applied to the new bone. These influences do not justify acceptance of inaccuracies, of course. The treatment plan needs to be as accurate as possible and afterwards – if acceptable to the patient – this plan has to be carried out as accurately as possible.[13, 14] Small malpositions that might occur can then be addressed by molding.

Finally, the outcome of both techniques needs to be compared under clinical circumstances to decide ultimately which technique represents the "overall gold standard."

CONCLUSIONS

The question about the "gold standard" for the exact placement of a (semi-)buried intraoral distraction device remains open. To date, template-coded positioning seems to guarantee the highest level of precision, but some influencing factors have not been addressed yet.

CAPTIONS

Figure 1. Mandible with registration splint and attached dynamic reference frame

Figure 2. View of the surgical plan for the right mandibular angle. (purple = target points at the angle; blue = fiducial for registration process)

Figure 3. Template with secure position defined through dentition as well as bone surface. The holes code the planned screw positions.

Figure 4. Realistic simulation of clinical setting with mandible mounted into phantom head

Figure 5. Screenshot of the navigation process. While the pointer is aimed directly at the planned screw entry position, the system shows an inaccuracy of 0.9 mm at label “left3”.

Figure 6a. Overlay of navigated results for the left ramus mandibula

Figure 6b. Overlay of navigated results for the right ramus mandibula

Figure 6c. Deviations from the plan for the navigated procedures on the left side

Figure 6d. Deviations from the plan for navigated procedures on the right side

Figure 7a. Overlay of template coded results on the left side

Figure 7b. Overlay of template coded results on the right side

Figure 7c. Deviations from the plan for template coded procedures on the left side

Figure 7d. Deviations from the plan for template coded procedures on the right side

Figure 8: Deviations from the plan for the navigated ("Brainlab") vs. the template coded ("Template") procedure. In comparison, the results from a previous study[10] with a manual ("Man SPL") procedure vs. an experimental navigation system ("Nav SPL"). The differences are significant.

Figure 9: Comparison of the inaccuracies of mesio-distal and cranio-caudal subgroups does not reveal a significant systematical error.

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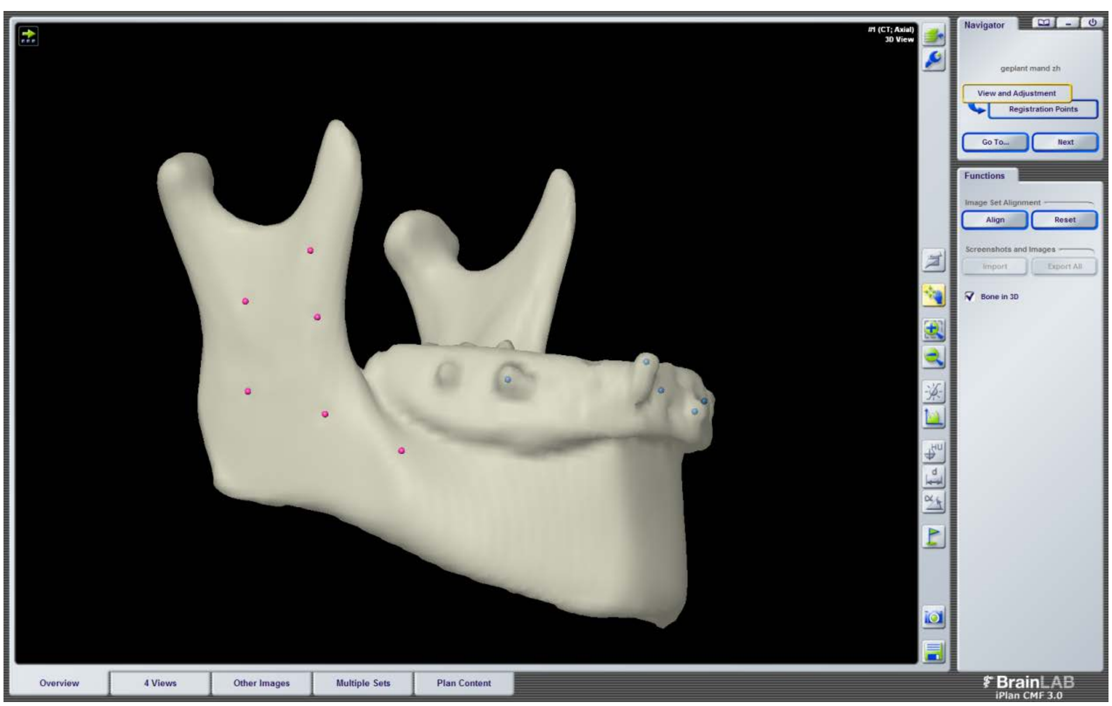
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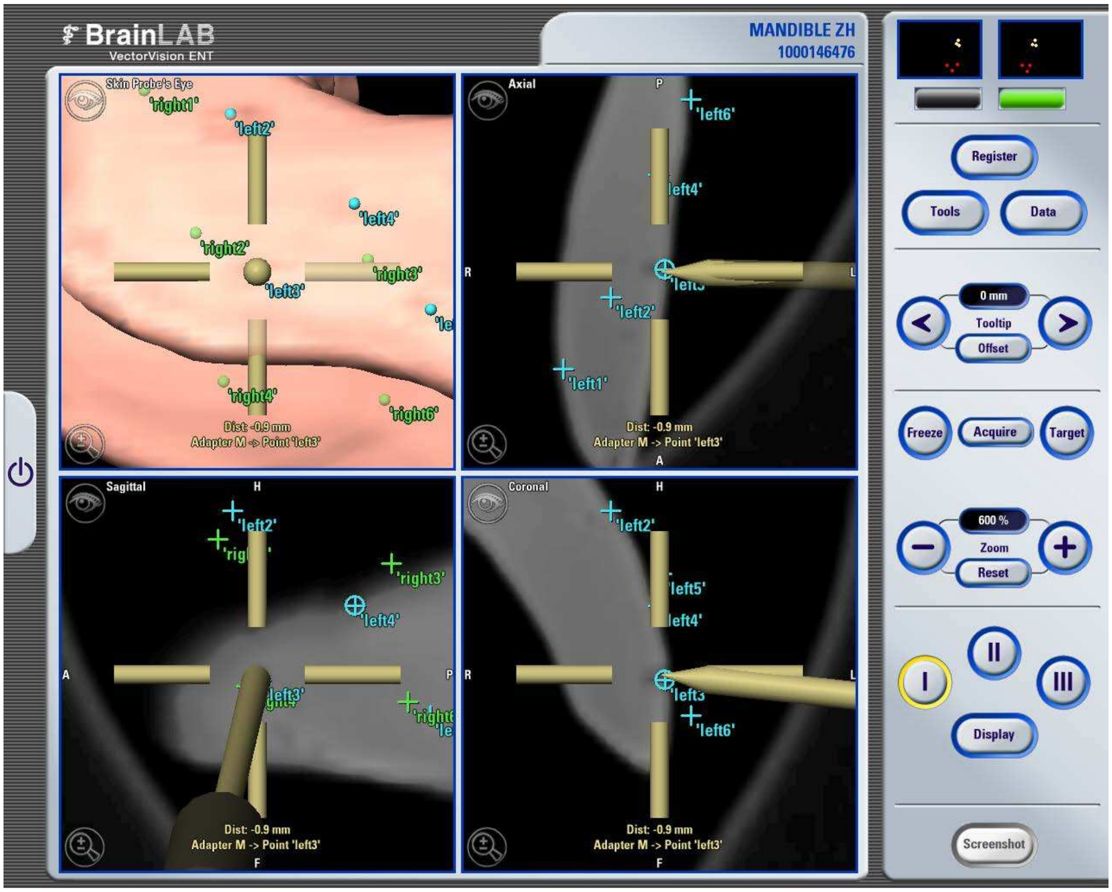
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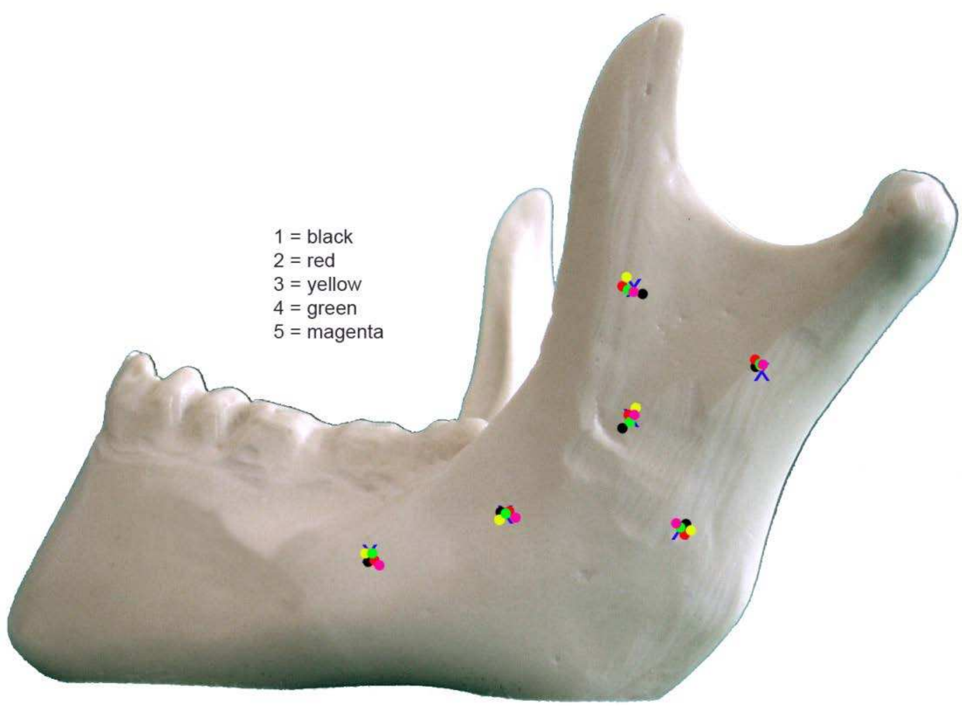
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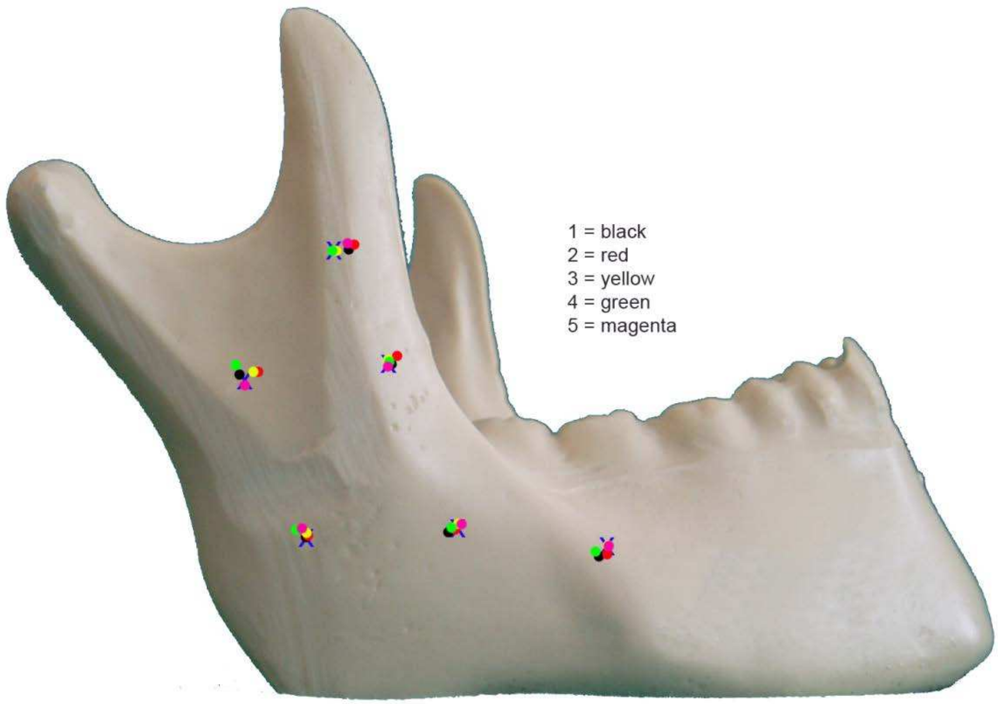
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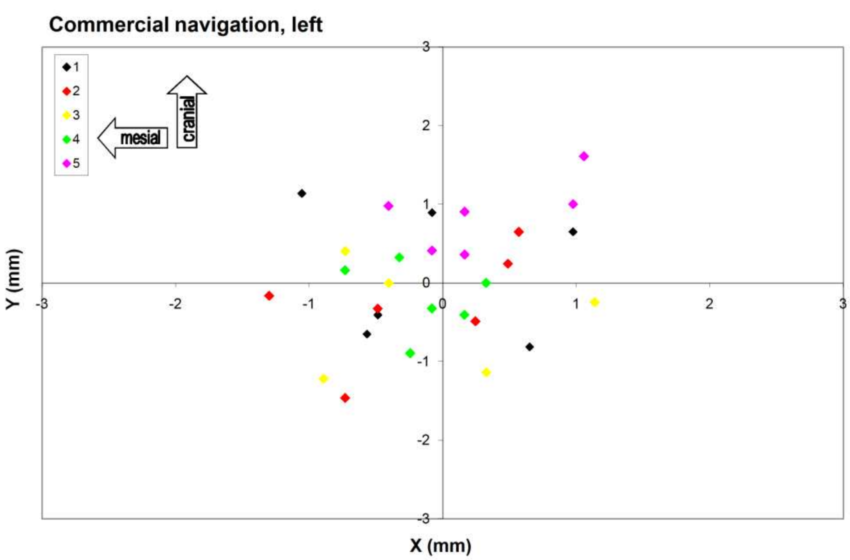
Commercial navigation, left
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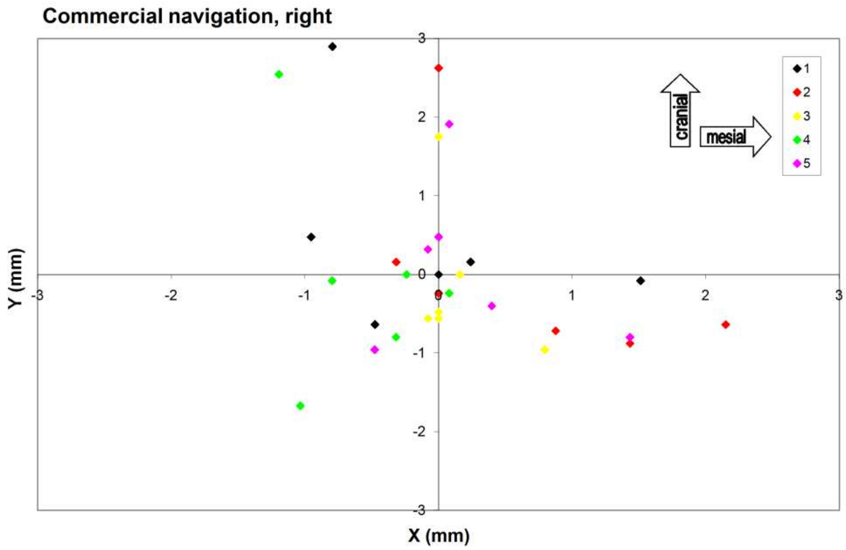
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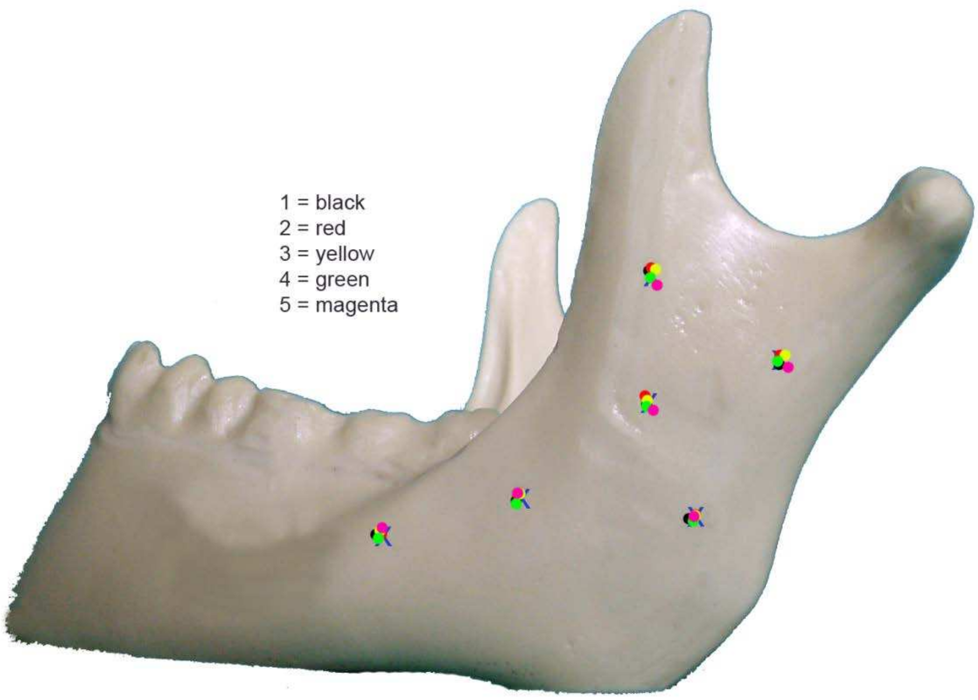
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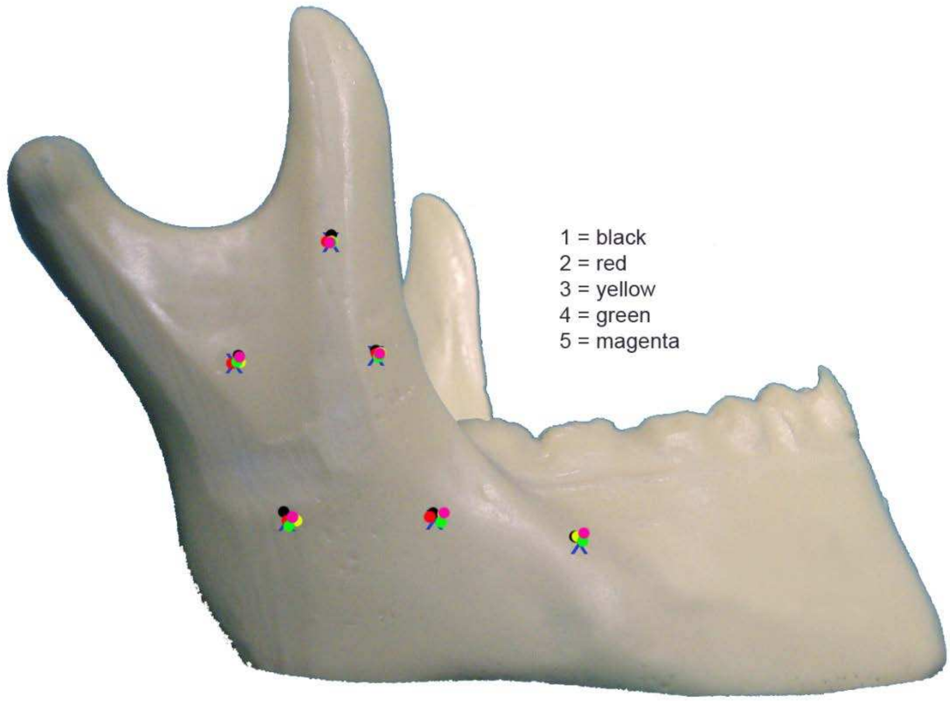
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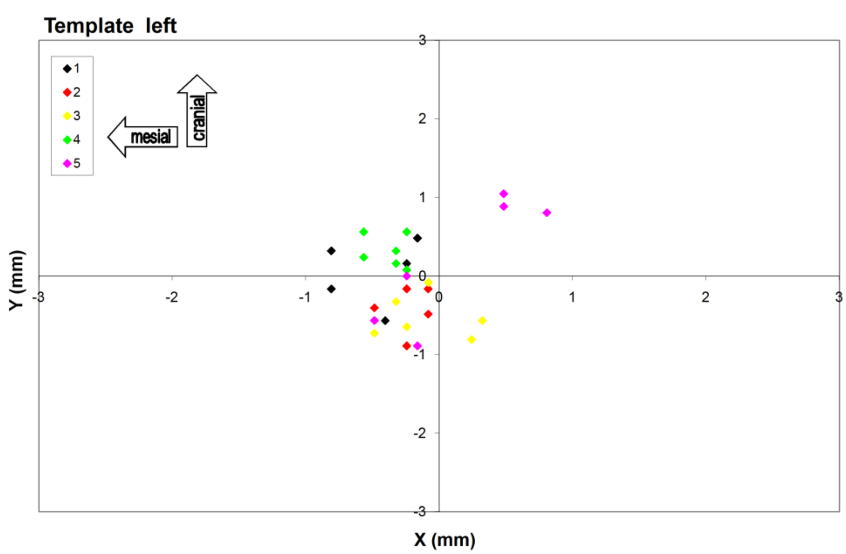
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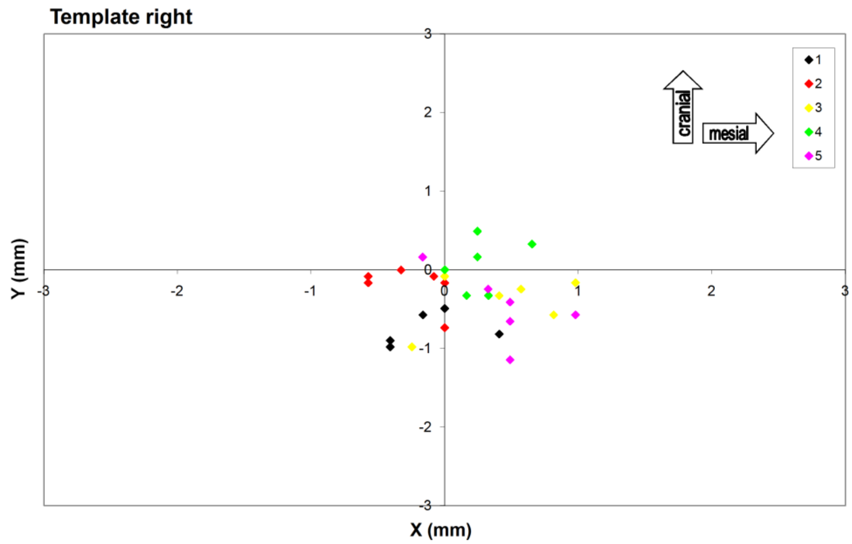
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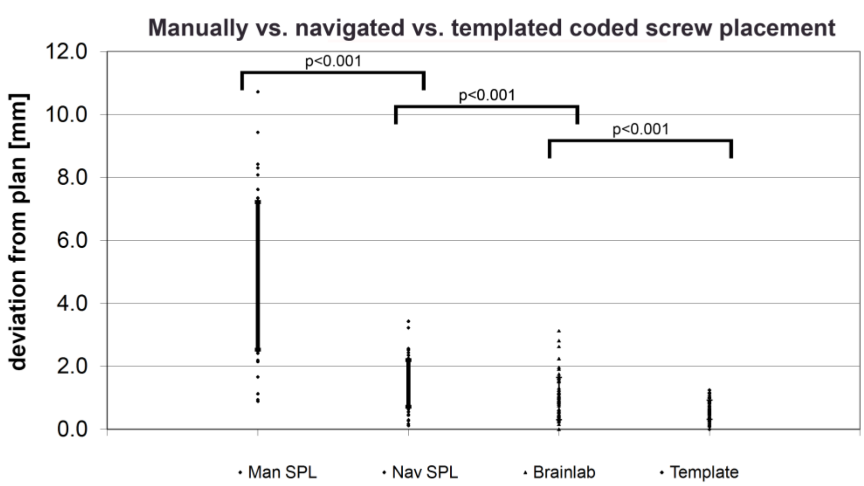
Manually vs. navigated vs. templated coded screw placement
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Man SPL
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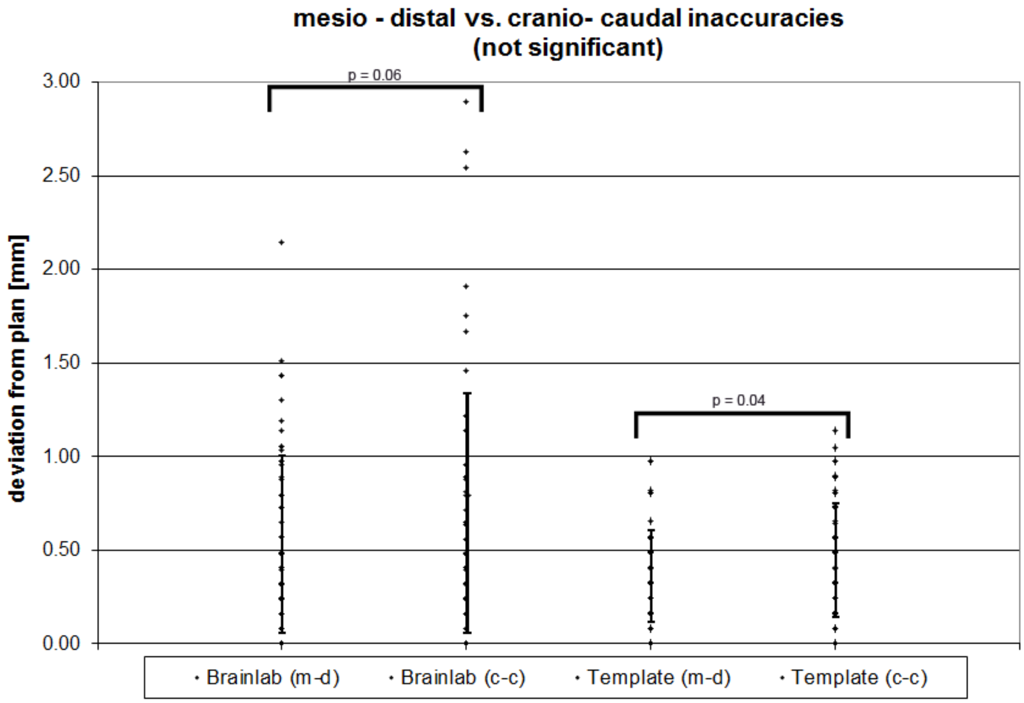
Brainlab
Template



mesio - distal vs. cranio- caudal inaccuracies
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Brainlab (c-c)
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Template (c-c)